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ABSTRACT

This is a summary of a report which presents three models quantifying the relationships between educational means (resources) and ends (pupil achievements) to analyze resource allocation problems within school districts: (1) the Pupil Performance Model; (2) the Goal Programming Model; and (3) the Operational Structure of a School and Pupil Performance Model. These models reduce educational data to manageable equations by applying educational economic concepts and quantitative methods. They can be used to address two of New York state's major educational policy predicaments: (1) What is the best composition of financial resources (by function) to produce predetermined levels of educational ends in a given type of school district while considering its pupil and community attributes? and (2) What administrative adjustments can be implemented by a given educational jurisdiction to attain some predetermined (and unified) educational goals for an array of pupils with diverse attributes? A 20-item bibliography concludes the document. (BS)

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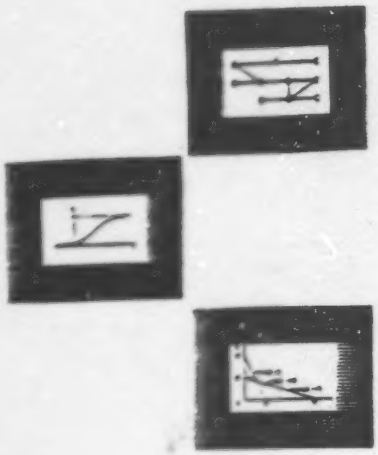

PUBLIC EDUCATION RESOURCES AND PUPIL PERFORMANCE MODELS
A Summary Report

by
D. Spottheim et. al.

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August 1984

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by
D. Spottheim et. al.†
LIRPB Hauppauge, N.Y.

Aug. 1984

I. INTRODUCTION

The rising cost of rendering educational services and the concurrent increase of tax burden to finance these services have intensified the debate concerning the relationships between educational outcomes and expenditures on public education services. Lately, this debate has been transformed into a public demand for improved services through the adoption of "effective" teaching methods and efficient resource utilization policies [see Shorr in WSJ Dec. 15, 1983]. Concurrently, various commissions were established to investigate the educational problems and their recommendations were widely reported in the printed media [WSJ Dec. 23, 1983; N.Y. Times Nov. 13, 1983]. In essence these recommendations call upon the public educational sector to implement policies such as:

- stiffer diploma requirements
- tougher academic standards
- improved teachers' qualifications
- improved guidance and counseling services
- longer hours in school

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*A summary of a final report with the same title (dated Aug. 1984). Research for this report was supported by a grant initiated by the Honorable Kenneth A. LaValle, New York State Senator, 1st District.

†These models were developed with the assistance of Paul C. Libassi, George R. Wilson and a contribution by Lester Dubnick. (See text for detail.)

While these recommendations are designed to improve the quality of education, they barely address the issue of effective utilization of educational and financial resources, while rendering such "new and improved" educational services. The lack of concern with the efficient resource allocation problem can be attributed to the prevailing view concerning administrative practices of the system. Although expenditure of monies (on educational services) is being audited by the state, the prevailing notion is that accounting and management practices (used by the schools) do not lend themselves to evaluate the effectiveness of these expenditures [see Wohlfred, 1970]. This notion can be challenged because the educational economics literature contains accepted theories and quantitative techniques that can be applied to this problem. Therefore, this synopsis summarizes the application of such methods to the efficacious educational resource utilization problems not addressed by the above mentioned commissions.

II. THE PROBLEM

Granted the egalitarian educational philosophy of the State of New York as reflected in the current administrative structure of the schools, and the commissions' recommendations, the problem of resource allocation within school districts can be stated as the following policy predicaments:

- What is the best composition of financial resources (by function) that would lead to a situation whereby a given type of school district would "produce" predetermined level of educational ends, while considering its pupils (and community) attributes.

- What administrative adjustments could be implemented by a given educational jurisdiction, in order to attain some predetermined (and unified) educational goals for an array of pupils (with diversed attributes)

Although these policy predicaments could be examined from various disciplinary points of view, it was decided to use those (economics) theories and quantitative methods that were employed by investigators while analyzing analogous (or homologous) problems. These theories were supplemented by concepts culled from related fields, and the methods were tempered with newly advocated biostatistical and management science concepts. In using this amalgamated approach, an array of administrative data were reduced to a manageable set of equations thereby gaining a better understanding of the educational phenomena in question.

III. THE APPROACH

It was asserted in the literature, that these predicaments can be addressed through the application of quantitative techniques portraying the efficaciousness of:

- resource allocation within school districts (see Cohn and Hillman, 1975; Fox, 1972; Morgen, 1977).
- pupil "movement" within the existing operational entities of a school system. (See Rosenblatt, 1960; Enscore, 1972; Spottheim, 1974, 1975.)

Hence, three models were constructed. The first is a discriptive model, portraying the relationships between educational expenditures incurred, and the outcomes produced by school districts. A resource allocation procedure was then used in conjunction with this model. This amalgamated approach was used to determine the composition of financial resources needed to realize educational goals for various kinds of districts. Finally, a model portraying operational structure of a school system and its outcomes was developed. The units of analysis of this model are <u>pupils</u>, while the units of analysis of the former models are school <u>districts</u>. A brief discussion concerning these models is provided below;

IV. THE MODELS

The springboard used to develop The Pupil Performance and Resource Utilization Model [Spottheim/Libassi, 1984] are empirical studies portraying

the quantitative relationships between educational means (resources) and ends (outcomes). This model consists of 18 equations. Each of the equations shows the quantitative relationships between a particular educational outcome (end) and a set of expenditures (by educational function). An outcome is measured in terms of a probability that a school district will "produce" a predetermined educational outcome (i.e., probability that its pupils pass a given state-administered test). The expenditures (per enrollee) are the "explanatory" variables (or education means) of the model. While these outcomes measure the so-called "higher order reasoning", they do not measure what the pupils "actually learned". However, it was decided to use these probabilities, because variables depicting what was "actually learned" are not ubiquitously available.

The model just discussed is a descriptive model portraying the relationships between educational means and ends, while the second model deals with the application of a "prescriptive" method (i.e., goal programming) used in conjunction with that model [Spottheim/Wilson, 1984]. Specifically, this approach concerns itself with the application of goal programming techniques to the problem of efficacious resource allocation within the school districts to ascertain a desired level of achievement (outcomes or outputs). This resource allocation procedure was realized through a belated, but useful, process of amalgamating econometric and operations research techniques.

The third model is based on an approach which portrays the operational structure, processes, and outcomes of a single school district quantitatively [Spottheim et. al., 1984].** The units of analysis (cases) in this model are pupils, while the cases (observations) in the aforementioned models are school districts. The central theme behind this model is that the complex operational structure of a school system and its outcomes can be mathematically represented, through the application of a "complex linear flow" technique . The model was developed through a rapproachment of organizational theories and management science techniques.

**This model was developed by Spottheim/Wilson and with a contribution by Dubnick.

A. The Pupil Performance Model

This model is composed of 18 logistic equations. As was noted earlier, it depicts the "technical relationships" between educational means (resources) and ends (outcomes). The latter variables depict the probability that a pupil enrolled in a particular district has;

- scored above state reference point (SRP) in selected 3rd and 6th grades proficiency exams administered by New York State.
- scored above SRP in selected Regents competency tests (RCT) for grades 9-11.
- passed selected Regents graduation requirement tests.
- graduated high school and left for a 4-year college.
- graduated high school and left for a 2-year college and other institutions.
- graduated high school and left for employment, military service.
- dropped out of school.

To generate these ends (outputs), school districts are said to employ financial and manpower resources as inputs. Such inputs are denoted in the model by per-pupil expenditure on:

- instructional salaries
- non-instructional salaries
- equipment, supply, material and testbooks
- contractual, BOCES, and other categorical services and programs.

The premise behind these explanatory (input) variables, is that they represent a special case of "factors of educational production", and the sum of these financial variables virtually cover the entire "approved operational budget" (per pupil) of the district.[1]

[1]Average teacher salary is not part of this budget. It merely reflects the average salaries by districts. Also, the expenditures specified throughout this report are in constant (1980) dollars.

Additionally, community attributes (resources beyond the control of the school district) also influence the educational outcomes. Hence, it was hypothesized that a variable denoting the district "wealth" (income net worth) can be used as a surrogate depicting the community contribution (inputs) to the educational process.

Finally, non-financial variables were said to influence the outcomes. Hence, it was hypothesized that indices denoting teachers and school attributes will influence the outcomes. These outcomes were said to be tempered by (qualitative) indices denoting pupil performance (or "quality" of pupils) in a previous year. Thus, non-financial indices (included in the model) depicts the following attributes:

- number of book titles in the school library
- school district size
- crowdedness (Sq./ft. per pupil)
- teacher's qualification/experience
- pupils quality or previous year performance

To construct the data base for this model, about 150 school finance and accounting items along with a score of pupil performance indicators, as well as dozens of non-financial indices were culled from eclectic administrative sources for each school district located in Suffolk County, N.Y. This data base (for 72 districts) was then analyzed through the application of multivariate statistical methods and aggregated into a set containing some 100 variables. Consequently, a matrix containing 54 cases (school districts) and 58 variables was constructed as the data base of the model. The variables used to construct the model are defined below in Table I, while the structure of the model is presented pictorially in Chart I that follows:

TABLE I

LIST OF VARIABLES USED TO CONSTRUCT THE MODEL

I. RAW DEPENDENT VARIABLES

A. Exam Results (Elementary School); Probability Measurements

Var. No.	
O_1	Reading Exam 3rd Grade - Above State Reference Point (SRP)
O_2	Math " " " " " " "
O_3	Reading Exam 6th Grade - " " " "
O_4	Math " " " " " " "

B. RCT Exam Results (Sec. Schools); Probability Measurements

O_5	Math Exam 9th Grade - Above SRP
O_6	" " 10th " " "
O_7	" " 11th " " "
O_8	Reading " " " " "
O_9	Writing " " " " "

C. Regents Graduation Exams; Probability Measurements

O_{10}	Regents English Exam - Above SRP
O_{11}	" Math 10 " " "
O_{12}	" Biology " " "
O_{13}	" Chemistry " " "
O_{14}	" Social Studies " "

D. Destination of High School Graduates; Probability Measurements

O_{15}	Post Secondary 4 Years College
O_{16}	Post Secondary 2 Years College
O_{17}	Employment/Military
O_{18}	Dropout
O_{19}	Other

II. TRANSFORMED DEPENDENT VARIABLES (LOGIT)

A. Exam Results (Elementary School)

Q_1	Reading Exam 3rd Grade - Above State Reference Point (SRP)	$ln\ O(1)/[1-O(1)]$**
Q_2	Math " " " " " " "	$ln\ O(2)/[1-O(2)]$
Q_3	Reading " 6th " " " " "	$ln\ O(3)/[1-O(3)]$
Q_4	Math " " " " " " "	$ln\ O(4)/[1-O(4)]$

B. RCT Exam Results (Sec. Schools)

Q_5	Math Exam 9th Grade - Above SRP	$ln\ O(5)/[1-O(5)]$
Q_6	" " 10th " " "	$ln\ O(6)/[1-O(6)]$
Q_7	" " 11th " " "	$ln\ O(7)/[1-O(7)]$
Q_8	Reading " " " " "	$ln\ O(8)/[1-O(8)]$
Q_9	Writing " " " " "	$ln\ O(9)/[1-O(9)]$

**ln = A symbol denoting natural log.

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C. Regents Graduation Exams

Q_{10}	Regents English Exam - Above SRP	$\ln 0(10)/[1-0(10)]$
Q_{11}	" Math 10 " " "	$\ln 0(11)/[1-0(11)]$
Q_{12}	" Biology " " "	$\ln 0(12)/[1-0(12)]$
Q_{13}	" Chemistry " " "	$\ln 0(13)/]1-0(13)]$
Q_{14}	" Social Studies " " "	$\ln 0(14)/[1-0(14)]$

D. Destination of High School Graduates

Q_{15}	Post Secondary 4 Years College	$\ln 0(15)/[1-0(15)]$
Q_{16}	Post Secondary 2 Years College	$\ln 0(16)/[1-0(16)]$
Q_{17}	Employment/Military	$\ln 0(17)/[1-0(17)]$
Q_{18}	Dropout	$\ln 0(18)/[1-0(18)]$

III. EXPLANATORY, FINANCIAL RESOURCE AND OTHER INPUT VARIABLES

A. Financial Resource Variables (Measured in dollar per pupil unit)

Var. No.	Var. Code	
X(1)	FRV2	Instructional Salaries - Chief School Admin.
X(2)	FRV3	Instructional Salaries - Admin., Improvmnt. & Planning
X(3)	FRV4	Instructional Salaries of Teachers K-6 per grade K-6 enrollment
X(4)	FRV5	Instructional Salaries - Teachers 7-12 per grade 7-12 enrollment
X(5)	FRV7	Total Expenditure for PSEN per PSEN Pupil†
X(6)	FRV10	Instructional Salaries - Pupil Health, Psych. Soc. Ser.
X(7)	FRV12	Total Interscholastic Athletics
X(8)	FRV14	Community/Youth Service-Instructional Salaries
X(9)	FRV19	Average Teacher Salary Total (K-12) (Not per pupil unit)
X(10)	FRV20	Other Instructional Expenditures (i.e. substitute teachers)
X(11)	FRV21	School Library Total
X(12)	FRV22	Computer Service/Ed. TV Total
X(13)	FRV24	Co-Curricular Total
X(14)	FRV25	General Support & Empl Benefit (overhead)
X(15)	FRV26	Pupil Transport. & Main ain. Total (overhead)
		BOCES
X(16)	FRV27	BOCES-Adm/Plan/Improvement Expenditure
X(17)	FRV28	BOCES-Inst. Teaching
X(18)	FRV29	BOCES-Pupil & Comm. Services
		CONTRACTUAL (& TUITION)
X(19)	FRV31	Contractual-Adm/Plan/Improvement
X(20)	FRV32	Contractual-Inst. Teaching and Tuition
X(21)	FRV33	Contractual-Pupil & Comm. Services
		BOCES & CONTRACTUAL
X(22)	FRV36	Instructional-BOCES & Contractual (FRV28 + FRV32)

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SUPPLY MATERIAL, TEXTBOOK & EQUIPMENT

X(23)	FRV47	Admin/Plan/Improvement (FRV39 + FRV43)
X(24)	FRV48	Instructional teaching (FRV40 + FRV44)
X(25)	FRV49	Pupil and Community Services (FRV41 + FRV45)

NON-INSTRUCTIONAL SALARIES

X(26)	FRV51	Non-Inst. Sal.-Adm/Pln/Improvement/Teaching
X(27)	FRV52	Non-Inst. Sal.-Pupil & Comm. Services

B. Teacher/School, Community and Pupil Attributes Indices

X(28)	TSCP1	No. of Book-Titles in the Library
X(29)	TSCP2	School Size Index (1 if more than 4800 pupils; 0 Otherwise)
X(30)	TSCP7	Sq./ft. of Class Room per Pupil-a crowdedness index
X(31)	TSCP8	School Teacher Characteristics Index
X(32)	COM2	Income per Return - denotes community attributes
X(33)	COM3	Community Wealth Index

C. Pupil Characteristics Previous Year

X(34)	APNX1	3rd grade pupil perf. index time "t-1"++
X(35)	APNX2	6th grade " " " " "
X(36)	APNX3	9th grade math RCT " " "
X(37)	APNX4	10th grade math RCT " " "
X(38)	APNX7	Regents English " " "
X(39)	APNX8	Regents Math 10 " " "
X(40)	APNX9	Regents Biology " " "

+PSEN is an acronym for pupils with special educational needs.

++ Note $APNX_i$ are binary (dummy) variables.

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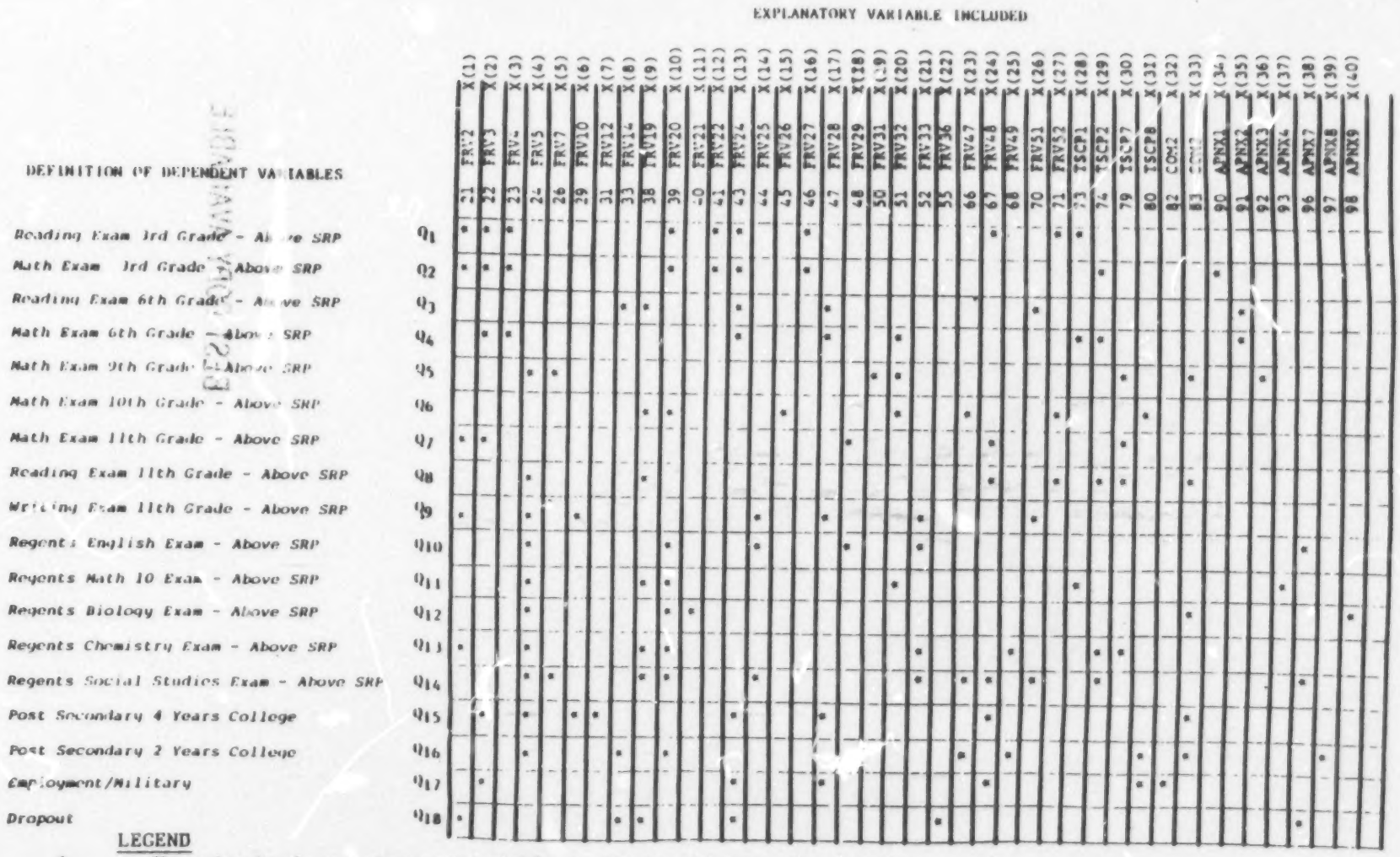
CHART I

A Pictorial Representation of the Hypothesized Model



LEGEND

* = Hypothesized explanatory variable to be included in the equation.

Q_i = Equation no. and symbolic representation of a transformed dependent variable O_i

FRV, TSCP, COM, APNX = Code of explanatory variable.

X(i) = Sequence no. of explanatory variable.

B. The Goal Programming Model

While a resolution of the aforementioned policy predicaments may be perceived by some to be a formidable task, it is not, inasmuch as scholars have developed quantitative approaches for simulating such a policy predicament concerning financial resource allocation. (see Fox, 1972; Sengupta and Fox, 1971; Morgan, 1977). The approach used by these scholars is based on the reconciliation of operations research and econometric techniques.

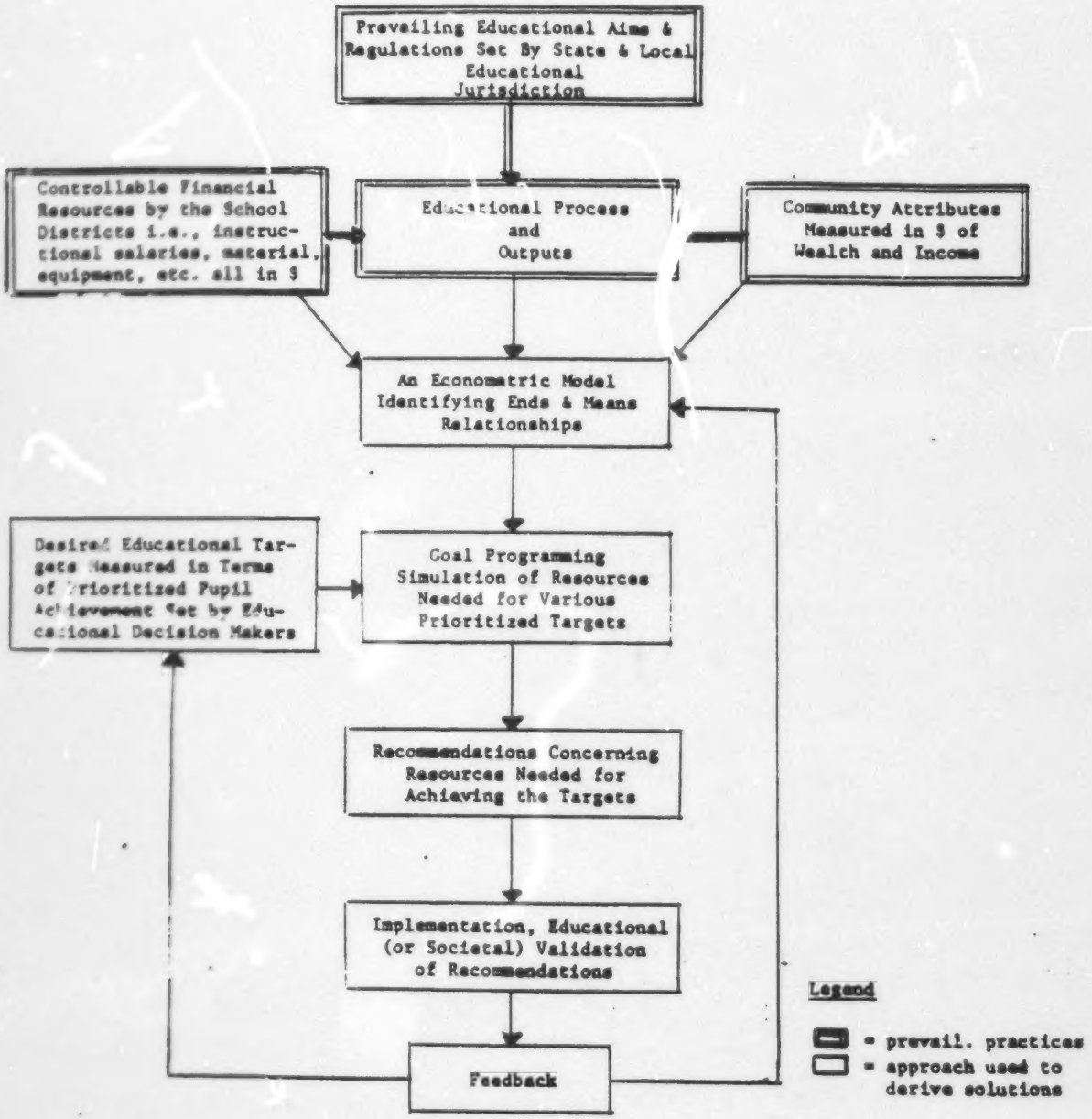
The central theme of this endeavor is that the mixed financial resources (by educational function, i.e., instructional salaries, equipment, supply, material) can be adjusted so as to approach the "production possibilities frontier" with respect to predetermined educational goals (or targets). Hence, the composition of financial resources needed to realize these goals is determined in the "prescriptive" model through the application of a "goal programming" technique in conjunction with the above mentioned "pupil performance model".[2] This amalgamation of techniques is an accepted methodology in the field of management science in general, and educational finance in particular. Cohn and Morgan (1977) and Fox (1972) have suggested this approach, while Morgan (1977) demonstrated its applicability to educational resource allocation problems.

To demonstrate the applicability of this approach (with respect to the predicaments mentioned above), a series of scenarios were formulated and solutions for various types of school districts (i.e., low, high wealth) were simulated. Since this goal programming technique was used in conjunction with the pupil performance model, the parameters and variables thereof are analogous related to those found in Table I and Chart I. A schematic representation of this simulation is presented below in Chart II.

[2]The application of this technique (to the resource allocation problem) espouses an a priori knowledge concerning; the desired (educational) targets, community wealth and "pupil quality" indices. The value of other (financial) variables are computed by the goal programming technique.

CHART II

Schematic Representation of Resource Allocation Procedure


Prevailing Educational Aims & Regulations Set By State & Local Educational Jurisdiction
Controllable Financial Resources by the School Districts i.e., instructional salaries, material, equipment, etc. all in $
Educational Process and Outputs
Community Attributes Measured in $ of Wealth and Income
An Econometric Model Identifying Ends & Means Relationships
Desired Educational Targets Measured in Terms of Prioritized Pupil Achievement Set by Educational Decision Makers
Goal Programming Simulation of Resources Needed for Various Prioritized Targets
Recommendations Concerning Resources Needed for Achieving the Targets
Implementation, Educational (or Societal) Validation of Recommendations
Feedback
Legend
= prevail. practices
= approach used to derive solutions

C. The Operational Structure of A School and Pupil Performance Model

Although the contention held by some that a school system is "too complex" for a quantitative inquiry, researchers in other fields have developed methodologies to address similar problems observed in other "human service organizations" [see Enscore, 1972; Hasenfeld, 1972; Spottheim, 1974, 1975]. Hence, a belated but useful process of amalgamating organizational theory [see Katz and Kahn, 1966; Thompson, J. M., 1973], management science techniques [Rosenblatt, 1960] along with complementary data, can be used to portray the operational structure, the educational system and its outcomes.

This approach espouses the disaggregation of the system into a set of educational components and outcomes. Since several factors influence the educational outcomes (ends) the components should portray both home environment and school attributes, namely:

- home and family environments
- pupil attributes
- teacher qualification/experience
- subjects taught
- pupil services available
- exam results (outcomes)

A primary pupil flow (activities) data was then collected and the data tabulated into a matrix, thereby allowing for the construction of a model which denotes the administrative interrelationships existing among the "sectors" (elements) of the systems in question, and between these sectors and the outcomes. Hence, such a descriptive model portrays

the educational system as network of "semi-autonomous" units which are linked together by a recurrent (routinized) flow of pupils, as was suggested in the literature [see Natale, Fall, 1981]. Unlike the previous models [Spottheim/Libassi, 1984]; Spottheim/Wilson, 1984] the units analysis of this model are pupils. Hence, detailed inferences can be drawn about the effect of the certain educational resources upon the performance of specific types of pupils. It should be noted that this methodology does not address the "pedagogical processes" used (within a unit or classroom) while teaching the pupils specific skills and knowledge. It only portrays the interrelationships between the existing elements (nodes) of the system.

To test the applicability of this approach, a "stratified sample" of 240 pupils enrolled in grades 3, 6, 9 (of a particular school district) was collected and a complex linear flow model was constructed. The theoretical foundation of this model as was noted earlier, is an amalgamation of organizational theories and management science techniques.

Upon collecting an augmented stratified sample of pupils enrolled in Grades 3 - 12, a comprehensive model will be constructed. This descriptive model could then be used in conjunction with an operations research technique to determine the "best pupil referral patterns" that may lead to the improvement of pupil performance in that school district.

V. THE RESULTS OF THIS ENDEAVOR

The models just presented were developed for the purpose of ascertaining simulated solutions for the aforementioned policy predicaments. Hence, comprehensive solutions were ascertained for one of these predicaments, whereas a partial solution was obtained for the second policy predicament. A discussion concerning these solutions is presented below:

A. Composition of Financial Resources Needed to Realize Educational Targets [3]

As was noted earlier, the goal programming technique was used (in conjunction with the pupil performance model) to estimate the achievable level of the predetermined educational targets and the corresponding financial resources for various types of school districts. The results presented henceforth are based on the premise that four major attributes influence the educational outcomes;

- Input or financial resources (by functions) used by the school district
- Teachers and/or school characteristics
- Community wealth
- School districts pupil quality

The first and second attributes are "educational factors of production" controlled by the schools, whereas the remainder are said to be beyond their control, and as such, they cannot be "manipulated" by the school

3 Notice estimated financial resources (by educational functions) presented henceforth are in constant (1980) dollars.

systems. To simulate the various scenarios, the school districts in question were "classified" in terms of pupil and community attributes which are beyond the control of the districts.

Hence, several explanatory variables (i.e., variables appearing on the right hand side of the pupil performance model) were "pegged" at a given value. The community attribute (X_{33}), for instance, was fixed at one of three values reflecting low, average or high community wealth index, whereas the school size index X_{29} (which is a binary variable) was pegged so as to denote whether the school district enrollment is greater or less than 4800 pupils. On the other hand, the seven pupil characteristics (X_{34} - X_{40}) are dichotomous variables which were set at specific values. They denote whether the pupils (enrolled in a given district) performed (in a previous year) above, or below, county average (or at the county average level). These variables were chosen inasmuch as they depict the community "contribution" to the educational process and the "quality of pupils" of a district, respectively. Since these variables do influence the outcomes (and resource requirement) they were used to define the socioeconomic educational environment of the following types of cases:

- a large school district (Case I)
- a district in transition (Case II)
- various types of districts within a given region (Case III)

The goals, the desired target (outcome) values (O_1 - O_{18}) and several indices reflecting the community and pupil attributes (which are beyond

the control of the schools; X_{32}-X_{40}) all were determined in collaboration with school administrators for each of the cases. Overhead (financial) variables (X_{14}-X_{15}) were also fixed (pegged), while simulating the solutions for these cases. Alternative scenarios for each case were then formulated and solutions were simulated.

In simulation solutions for Case I - a large school district - two alternative scenarios were formulated for two alternative budget configurations (in 1980 dollars) for each, (i.e., $3506 per pupil and $3150 per pupil). The scenarios in this case are reflected in terms of alternative priority classes for the outcomes - they are as follows:

Case I - Priority Classes

Outcome Code	Scenario 1	Scenario 2
O_1 - O_4	2	2
O_5 - O_7	3	4
O_8 - O_9	4	5
O_{10} - O_{14}	5	3
O_{15} - O_{16}	6	6
O_{17} - O_{18}	7	7

Case II - a school district in transition on the other hand, contains solutions for three different scenarios and two budget configurations for each scenario. The same can be said for Case III. Finally,

seven prioritized goals were specified for Cases II-III and their respective scenarios. It should be noted, however, that in all cases, the first priority concerned the budget constraints, while the remainder dealt with the desired educational targets.

Case I - A Large School District

The application of the goal programming technique to the resource allocation problem of a large school district will now be presented. This case as was noted earlier, contains two alternative scenarios. In both scenarios there are seven priority classes. The first priority concerned the budget constraints, whereas the remainder deal with the educational (outcomes) targets. These desired outcomes (as was noted earlier) were defined as "transformed" probability. The school district in question is characterized by having the following school community and pupil attributes during the 1979-80 school year:

Variable Code		Case I - Value
X_{29}	$TSCP_2$	1
X_{32}	COM_2	$15,000
X_{33}	COM_3	$50,000
X_{34}	$APNX_1$	0
X_{35}	$APNX_2$	.5
X_{36}	APN[illegible]	.5
X_{37}	$APNX_4$	.5
X_{38}	$APNX_7$	0
X_{39}	$APNX_8$	0
X_{40}	$APNX_9$	.0

The desired target value (O_1-O_{18}) was provided by administrators of this school and several other variables were fixed at a predetermined value. Hence, the overhead variables (X_{14},X_{15}) were fixed at \$1120 and \$530 respectively, and X_5 was fixed at \$50. All other financial variables were determined by the goal programming technique. However, these variables were constrained by lower or upper bounds. The desired educational targets (see Table II, Col. 5), priority for scenarios 1 and 2, weight and the bounds all were derived through consultation with a staff member of the school district in question.

The results of this endeavor are presented in Table II that follows. It contains solutions for scenario 1 and scenario 2, and other relevant information. Hence this table contains 9 columns of information denoting:

Col. No.	Definition of Information
1.	Variable Code
2.	Mean Value
3.	Lower Bound
4.	Upper Bound
5.	Desired Target (educational)
6.	Scenario I Solution (for a budget of \$3506 per pupil)
7.	Scenario I Solution (for a budget of \$3150 per pupil)
8.	Scenario II Solution (for a budget of \$3506 per pupil)
9.	Scenario II Solution (for a budget of \$3150 per pupil)

Table II

Case I Simulation Results

1 Outcome Variable Code	2 Mean Value	3 Lower Bound Value	4 Upper Bound Value	5 Desired Ed. Target	6 Scenario 1 Solution $3506/Pupil ‡	7 Scenario 1 Solution $3150/Pupil ‡	8 Scenario 2 Solution $3506/Pupil ‡	9 Scenario 2 Solution $3150/Pupil ‡
O_1	.919	.8400	.9900	.90	.99	.99	.99	.99
O_2	.931	.7200	.9900	.93	.96	.99	.96	.99
O_3	.711	.4500	.9500	.85	.85	.85	.85	.85
O_4	.806	.4100	.9900	.88	.88	.88	.88	.88
O_5	.674	.3333	.9374	.75	.75	.75	.75	.75
O_6	.628	.3844	.9267	.65	.649	.649	.649	.649
O_7	.520	.2653	.9990	.50	.97	.98	.97	.98
O_8	.749	.1579	.9990	.90	.91	.899	.91	.899
O_9	.586	.2500	.8269	.75	.78	.75	.78	.75
O_{10}	.762	.3846	.9167	.90	.899	.82 *	.899	.82*
O_{11}	.760	.0588	.9608	.75	.80	.87	.80	.87
O_{12}	.810	.4091	.9990	.80	.799	.74 *	.799	.74*
O_{13}	.775	.1176	.9990	.85	.92	.97	.92	.97
O_{14}	.805	.2747	.9990	.85	.85	.92	.85	.92
O_{15}	.367	.1786	.8511	.30	.58	.51	.58	.44
O_{16}	.280	.1043	.4286	.30	.30	.30	.30	.30
O_{17}	.313	.0266	.5190	.20	.20	.03 *	.20	.04*
O_{18}	.180	.0068	.4786	.10	.08 #	.03 #	.08#	.03#

# indicates dropout (O_{18}) rate - below the desired target of .10

Input Variable Code/Name		Mean Value	Lower Bound Value [1]	Upper Bound Value [1]	Fixed Var.	SOLUTIONS FOR INPUT VARIABLES			
X_1	FRV_2	54.61	9.32	69.17		9	9	9	9
X_2	FRV_3	89.56	39.35	153.00		136	39	156	39
X_3	FRV_4	1092.54	795.56	1283.74		1396	1035	1396	1034
X_4	FRV_5	1444.61	1083.10	1593.55		1145	1085	1145	1089
X_5	FRV_7	50.72	5.22	120.00	50 +	(50)	(50)	(50)	(50)
X_6	FRV_{10}	70.01	39.47	145.00		39	39	39	39
X_7	FRV_{12}	36.05	15.49	55.69		15	15	15	15
X_8	FRV_{14}	.94	.01	10.00		0	0	0	0
X_9	FRV_{19}	19781.75	16677.56	24000.00		20535	16748	20535	16739
X_{10}	FRV_{20}	31.17	15.94	100.00		16	16	16	16
X_{11}	FRV_{21}	56.03	15.91	76.40		24	0	24	0
X_{12}	FRV_{22}	3.17	.01	10.68		0	0	0	0
X_{13}	FRV_{24}	9.88	2.05	17.07		22	37	22	34
X_{14}	FRV_{25}	1120.82	860.45	1306.08		(1121)	(1121)	(1121)	(1121)
X_{15}	FRV_{26}	530.88	409.45	800.00		(531)	(531)	(531)	(531)
X_{16}	FRV_{27}	1.32	.01	20.00		0	0	0	0
X_{17}	FRV_{28}	66.73	32.70	140.00		32	82	32	82
X_{18}	FRV_{29}	1.20	.01	3.01		12	0	12	0
X_{19}	FRV_{31}	5.33	.81	12.17		0	43	0	43
X_{20}	FRV_{32}	17.16	3.86	50.00		92	60	92	60
X_{21}	FRV_{33}	8.63	3.22	16.51		3	3	3	3
X_{22}	FRV_{36}	83.89	42.00	140.27		125	143	125	143
X_{23}	FRV_{47}	3.93	.63	25.00		2	1	2	1
X_{24}	FRV_{48}	69.77	40.80	120.00		40	40	40	40
X_{25}	FRV_{49}	2.56	.91	8.00		0	0	0	0
X_{26}	FRV_{51}	56.33	31.72	500.00		31	31	31	31
X_{27}	FRV_{52}	21.23	9.30	34.15		9	9	9	9
X_{28}	$TSCP_1$	15.08	5.76	31.02		31.0	31.0	31.0	31.0
X_{29}	$TSCP_2$	.50	0	1.0	1+	(1.0)	(1.0)	(1.0)	(1.0)
X_{30}	$TSCP_7$	27.93	20.44	45.92		35.3	41.0	35.3	41.1
X_{31}	$TSCP_8$	43.45	31.70	56.15		31.7	31.7	31.7	31.7
X_{32}	COM_2	18683.76	14669.40	22758.90	15000+	(15000.0)	(15000.0)	(15000.0)	(15000.0)
X_{33}	COM_3	76716.81	44893.80	126186.00	50000+	(50000.0)	(50000.0)	(50000.0)	(50000.0)
X_{34}	$APNX_1$	.6	0	1.0	0.0 +	0.0	0.0	0.0	0.0
X_{35}	$APNX_2$	.5	0	1.0	0.5 +	0.5	0.5	0.5	0.5
X_{36}	$APNX_3$	.5	0	1.0	0.5 +	0.5	0.5	0.5	0.5
X_{37}	$APNX_4$	.5	0	1.0	0.5 +	0.5	0.5	0.5	0.5
X_{38}	$APNX_7$	.4	0	1.0	0.0 +	0.0	0.0	0.0	0.0
X_{39}	$APNX_8$	.4	0	1.0	0.0 +	0.0	0.0	0.0	0.0
X_{40}	$APNX_9$	.4	0	1.0	0.0 +	0.0	0.0	0.0	0.0

[1] 53 School Districts included (Fishers Island excluded). Upper bound is the mean of the upper 20% of S.D. Similarly, the lower bound is the mean of 20% of S.D.

‡ indicates budget slack = 0

* indicates objective (target) not met

( ) figure in parenthesis indicates fixed variable

+ denotes variable fixed at the indicated value

# indicates dropout (O_{18}) rate exceeded the desired target of .10

Budget constraint of $3506 per pupil implys:

$$\sum_{k=1}^{27} C_k X_k \leq 3506 \; ; \; k \neq 9, 22$$

Where:

C_k = .55, k = 3 (proportion of students K-6)
.45, k = 4 (proportion of students 7-12)
.1, k = 5 (proportion of students under PSEN)
1.0, otherwise

The mean value (Col. 2, Table II) of an outcome "O_i", for example, depicts the probability that an average school district (located on Long Island) will "produce" an outcome "i." The lower and upper bounds denote that probability for the upper and lower 20% of the districts respectively.

On the other hand, the mean value of an input variable "X_i" depicts the expenditure (per pupil) of an average school district, whereas the lower and upper bounds of that variable depict that expenditure for the upper and lower 20% of the districts, respectively.

The solutions recorded in Table II indicate that the results for the two scenarios are similar. For instance, a comparison of the results of Scenario 1 (budget of $3506 per pupil) against those of Scenario 2, reveals that all desired education targets can be met (with a budget of $3506/pupil) even though the scenarios differ in their priority classes. On the other hand, a comparison of Scenario 1 results (with a budget of $3150 per pupil) against the results of Scenario 2 (as denoted in column 9) shows that certain targets cannot be met in both scenarios. In other words, the desired targets (regardless of their priority classes) can be realized providing the total school budget is at least $3506 per pupil. Hence a reduction of that budget is unwarranted for this school, because the "budget slack" is equal to zero, for both scenarios. In addition to the above, the distribution of such a budget over the various functions (i.e., variables X_1- X_{27}),has some policy implications -- which are discussed below.

One way of examining the distribution of that budget ($3506/pupil) over the various education functions (i.e., input variables denoted in column 1, Table II) is to compare the money allocated by the goal programming technique, against the mean value of these functions (i.e., column 2, Table II). For instance, simulation technique allocated for functions X_1-X_4 the following amount of money, 9, 156, 1396 and $1143 respectively (see col. 6), whereas the mean values of the same educational functions are: 54.61, 89.56, 1092.54, and $1444.44 respectively (see col. 2, Table II). In other words, the results of the simulation technique call for more financial resource to be allocated for functions; X_2 (adm. improvement and planning) and X_3 (instructional salaries K-6), whereas less money should be spent on functions X_1 and X_4. A decreased expenditure on X_4 implies that the pupil/teacher ratio (for high schools) can be increased without affecting the outcomes. Also notice that the result for X_{13} (co-curricular) is larger than the mean value of that function. This solution seems to confirm a New Jersey education study which showed a positive relationship between co-curricular expenditures and pupil performances. The simulation results also show that the average teacher salary (X_9) and expenditure on contractual teaching (X_{10}) should be increased to a level above their respective mean values, whereas the crowdedness (X_{31}) and teacher qualification (X_{32}) indices for that district (Case I) should have the values of 35.3 and 31.7 respectively (see col. 6, Table II). The increase in the average teacher salary seems to complement a N.Y. State School Board Assoc. policy position (see Empire State Report Weekly, Vol. 10 No. 14, April 30, 1984).

Although several educational targets cannot be realized with a budget of $3150 per pupil, the distribution of that budget over the various functions warrants examination. For example, solutions generated for Scenario 1 with a total budget of $3150/pupil (see col. 7, Table II), revealed that more money should be allocated for functions; X_{13} (co-curricular), X_{17} (BOCES inst. teaching) and X_{19} (contractual-adm./planning/improvement), whereas less money should be allocated for functions: X_2 - X_4, and X_9 (aver. teacher salary).

Case II - A School District in Transition

The budget requirements for a school district in transition were simulated through the application of the same technique. To analyze this problem the Huntington Union Free School District was selected because its pupil performances, per pupil expenditures, community and pupil characteristics all resemble an "average" (or "abstract") Long Island district. Moreover, this district has gone through several stages of transition in the past 20 years. This transitional process may be intensified upon the completion of the high speed commuter rail to New York City.

Upon consultation with the School Superintendent, his staff (and with the approval of the Board of Education of that district) it was decided to simulate the resource requirements for three scenarios which reflect alternative socio-economic environments that the school may face due to migration (of various population groups) that may be caused due to the new rail system. A socio-economic environment as was noted earlier, is defined in terms of (predetermined) pupil, school and community (X_{32}, X_{33}) attributes which are beyond the control of the district. Hence, three scenarios (with two alternative budget configurations for each) were

examined: Scenario 1-low performing district, Scenario 2-average district, and Scenario 3 - high performing district. However, unlike the previous scenarios (see Case I) where such variables were fixed, in this case some variables were "bounded" on one side, that is, these variables were allowed to vary in one direction. The idea behind this bounding procedure was to test whether the simulation procedure can generate the value of certain attributes which are beyond the control of the district. The three scenarios of Case II were defined in terms of attributes (and/or variables) that were "bounded" (on one side) or "pegged" as follows:

Upper Bounds

Variable Code	Scenario 1 Low		Scenario 2 Average		Scenario 3 High	
X_5	$ 200	(Fixed)	$ 50	(Fixed)	5.2	(Fixed)
X_{28}	15	(LB)[3]	15.0	(MV)[2]	15	(UB)[1]
X_{29}	0	(LB)	.50	(MV)	1	(UB)
X_{30}	45.9	(LB)	45.9	(MV)	45.9	(UB)
X_{31}	31.7	(LB)	43.4	(MV)	56.1	(UB)
X_{32}	14,669	(LB)	18,668	(MV)	22,758	(UB)
X_{33}	44,893	(LB)	76,716	(MV)	126,186	(UB)
X_{34}	0	(LB)	.6	(MV)	1.0	(UB)
X_{35}	0	(Fixed)	.5	(MV)	1.0	(UB)
X_{36}	0	(Fixed)	.5	(MV)	1.0	(UB)
X_{37}	0	(Fixed)	.5	(MV)	1.0	(UB)
X_{38}	0	(Fixed)	.4	(MV)	1.0	(UB)
X_{39}	0	(Fixed)	.4	(MV)	1.0	(UB)
X_{40}	0	(Fixed)	.4	(MV)	1.0	(UB)

1 (UB) denotes variable was bounded by an Upper Limit only.
2 (MV) denotes variable was bounded by the Mean Value.
3 (LB) denotes variable was bounded by a Lower Limit only.

The overhead variables (X_{14} and X_{15}) in Case II, were fixed at a value of $867.0 and $409.0 respectively. The common educational (outcomes) targets, priority and weight (for all three scenarios) were determined through consultation with the Huntington district.

The results of the simulation effort are presented in Table III that follows. Table III consists of one page containing solutions for 3 scenarios (and two budget configurations for each scenario) along with other information; specifically, it contains 11 columns of information:

1 Variable Code
2 Mean Value
3 Lower Bound
4 Upper Bound
5. Desired Target
6. Scenario I Solution (for a budget of $3506 per pupil)
7. Scenario I Solution (for a budget of $3150 per pupil)
8. Scenario II Solution (for a budget of $3506 per pupil)
9. Scenario II Solution (for a budget of $3150 per pupil)
10. Scenario III Solution (for a budget of $3506 per pupil)
11. Scenario III Solution (for a budget of $3150 per pupil)

The solutions for Case II (see Table III above), can be used in the decision making process regarding the educational finance policies of a school district in transition. For instance, should the school district deteriorate into a low performing district (denoted by a value of "0" for variables X_{34} - X_{40}), the desired educational targets (see Table IV, col. 5, 7) will not be realized with a budget of $3150 per pupil. These targets, however, could be realized with a budget of $3506 per pupil, providing the community wealth index (X_{33}) is at least $44,894. Since the budget slack in this instance is equal to zero, it is unwarranted to reduce it below $3506/pupil. The distribution of that budget over the

TABLE III

Case II - A School District In Transition Simulation Results
Huntington School District

1	2	3	4	5	6	7	8	9	10	11
Outcome Variable Code	Mean Value	Lower Bound Value	Upper Bound Value	Desired Ed. Target	Scenario 1 Solution $3306/Pupil‡	Scenario 1 Solution $3150/Pupil‡	Scenario 2 Solution $3306/Pupil‡	Scenario 2 Solution $3150/Pupil‡	Scenario 3 Solution $3306/Pupil‡	Scenario 3 Solution $3150/Pupil‡
O_1	.919	.8400	.9900	.969	.96	.96	.96	.96	.96	.96
O_2	.931	.7200	.9900	.931	.93	.93	.93	.93	.93	.93
O_3	.711	.2500	.9590	.811	.83	.81	.84	.86	.84	.83
O_4	.806	.4100	.9903	.936	.95	.95	.95	.95	.95	.95
O_5	.674	.3333	.9324	.774	.77	.77	.77	.77	.77	.77
O_6	.628	.3844	.9267	.678	.91	.67	.93	.93	90	.82
O_7	.920	.2653	.9990	.94	.97	.98	.99	.99	.99	.93
O_8	.749	.1579	.9990	.[illegible]9	.97	.96	.99	.96	.98	.96
O_9	.586	.2500	.8269	.786	.78	.78	.78	.78	.78	.78
O_{10}	.782	.3846	.9167	.862	.86	.76*	.86	.86	.86	.86
O_{11}	.763	.0588	.9608	.96	.86	.76*	.86	.86	96	.86
O_{12}	.810	.4091	.9990	.96	.85	.78*	.85	.85	.85	.85
O_{13}	.775	.1176	.9990	.823	.63	.98	.98	.97	.99	.93
O_{14}	.803	.2747	.9990	.823	.91	.98	.82	.82	.82	.92
O_{15}	.367	.1786	.8511	.367	.56	.54*	.56	.56	.56	.56
O_{16}	.280	.1043	.4286	.38	.37	.18*	.37	.37	.37	.37
O_{17}	.313	.0266	.5190	.313	.14*	.0017*	.31	.31	.31	.31
O_{18}	.180	.0068	.4786	.08	.02	.0038	.01	.02	.021	.0316

SOLUTIONS FOR INPUTS VARIABLES

Input Variable Code/Name	Mean Value	Lower Bound Value[1]	Upper Bound Value[1]	Scenario 1 Solution $3306/Pupil‡	Scenario 1 Solution $3150/Pupil‡	Scenario 2 Solution $3306/Pupil‡	Scenario 2 Solution $3150/Pupil‡		
X_1 FRV_2	54.61	9.32	69.17	9	9	9	9	9	9
X_2 FRV_3	89.56	39.35	153.00	39	39	39	39	39	39
X_3 FRV_4	1092.54	795.56	1283.74	1990	795	1242	1406	967	930
X_4 FRV_5	1444.61	1083.10	1593.55	1083	775	1083	1083	1,083	1,083
X_5 FRV_7	50.72	5.22	120.00	(200)	(200)	(50)	(50)	(5)	(5)
X_6 FRV_{10}	70.01	39.47	145.00	39	39	39	39	39	39
X_7 FRV_{12}	36.05	15.49	55.69	58	15	115	77	128	56
X_8 FRV_{14}	.96	.01	10.00	0	16	0	0	0	0
X_9 FRV_{19}	19781.75	16677.56	24000.00	23,386	16,978	18,735	20,174	15,259	15,387
X_{10} FRV_{20}	31.17	15.96	100.00	16	16	16	16	16	16
X_{11} FRV_{21}	56.93	15.91	76.40	68	15	82	82	92	43
X_{12} FRV_{22}	3.17	.01	10.68	0	0	0	0	0	0
X_{13} FRV_{24}	9.88	2.05	17.07	40	73	6	38	44	38
X_{14} FRV_{25}	1120.62	860.49	1306.08	(867)	(86	(867)	(867)	(867)	(867)
X_{15} FRV_{26}	530.88	409.49	800.00	(409)	(409)	(409)	(409)	(409)	(409)
X_{16} FRV_{27}	1.32	.01	20.00	0	0	0	0	0	0
X_{17} FRV_{28}	66.73	32.70	140.00	208	479	117	81	129	212
X_{18} FRV_{29}	1.20	.01	3.01	13	0	7	7	0	0
X_{19} FRV_{31}	3.39	.81	12.17	44	90	79	79	66	23
X_{20} FRV_{32}	17.16	3.86	90.00	3	54	3	3	3	3
X_{21} FRV_{33}	8.63	3.22	16.51	3	3	3	3	3	3
X_{22} FRV_{36}	83.89	42.00	140.27	211	533	121	94	133	114
X_{23} FRV_{47}	3.93	.63	25.00	0	0	11	11	11	3
X_{24} FRV_{48}	69.77	40.90	120.00	40	40	132	74	152	92
X_{25} FRV_{49}	2.56	.91	8.00	2	0	0	0	0	3
X_{26} FRV_{51}	56.33	31.72	500.00	31	31	31	31	31	31
X_{27} FRV_{52}	21.23	9.10	34.15	9	9	9	9	9	9
X_{28} $TSCP_1$	13.08	3.76	31.02	10.4	0.0	11.4	10.5	10.4	10.0
X_{29} $TSCP_2$	.50	0	1.0	0.0	0.0	0	.9	0.0	0.0
X_{30} $TSCP_7$	27.93	20.44	45.92	25.5	41.2	45.9	45.9	45.9	29.1
X_{31} $TSCP_8$	43.65	31.70	58.15	NA	NA	NA	NA	NA	NA
X_{32} COM_2	18683.78	14869.60	22758.90	0.0	0.0	NA	NA	0.0	0.0
X_{33} COM_3	76716.81	44893.80	126186.00	44,894.0	44,894.0	0.0	0.0	0.0	67,187.1
X_{34} $APWX_1$	.6	0	1.0	(0.0)	(0.0)	0.9	0.0	0.0	0.0
X_{35} $APWX_2$	.5	0	1.0	(0.0)	(0.0)	0.5	0.5	1.0	1.0
X_{36} $APWX_3$	.5	0	1.0	(0.0)	(0.0)	0.5	0.5	1.0	1.0
X_{37} $APWX_4$	.5	0	1.0	(0.0)	(0.0)	0.5	0.5	1.0	1.0
X_{38} $APWX_7$	.4	0	1.0	(0.0)	(0.0)	0.41	0.4	1.0	1.0
X_{39} $APWX_8$	.4	0	1.0	(0.0)	(0.0)	0.0	0.0	0.0	0.0
X_{40} $APWX_9$	.4	0	1.0	(0.0)	(0.0)	0.0	0.0	0.0	0.0

[1] 33 School Districts included (Fishers Island excluded). Upper bound is the mean of the upper 20% of S.D. Similarly, the lower bound is the mean of 20% of S.D.

*Indicates objective was met

‡Budgetary slack = 0

‡Indicates dropout (O_{18}) rate exceed the desired target.

Note: Budget of $3306 per pupil implys:

$$\sum_{k=1}^{27} C_k X_k \leq 3506 \; ; \; k \neq 9, 22$$

Where:

C_k = .55, k = 3 (proportion of students K-6)
.45, k = 4 (proportion of students 7-12)
.1, k = 5 (proportion of students under PSEN)
1.0, otherwise

various functions has some policy implications. In Scenario 1 (poor district) for instance, the simulation procedure calls for the allocation of resources (financial) which are much larger than the county average for educational functions; X_3 (instructional salaries K-6), X_9 (av. teacher salary), X_{17} (BOCES - teaching), and X_{18} (BOCES - pupil and community service) and X_{19} (contractural adm./planning). In other words, to realize the preemptive targets or objectives (col. 3, Table III of Scenario 1 (poor district), it will be necessary to allocate much more resources for these educational functions. The increased spending on functions X_3 and X_9, for example, imply that the pupil/teacher ratio should be reduced for elementary schools, and "better" teachers (i.e., higher paid) should be hired. Also, increased expenditures on BOCES and contractual services will be required to realize the desired targets of this scenario.

Should the "pupil quality" indices (X_{34} - X_{40}) remain at the level indicated in Scenario 2 (see Table III, col. 8), the aforementioned targets can be realized with a budget of $3506/pupil and/or $3150/pupil regardless of the community index (X_{33}) value. The targets could be realized at the lower budget because of a "slack" of $367 per pupil that was observed while simulating Scenario 2 (with a budget of $3506/pupil). Notice that in this instance (Scenario 2) the allocation of funds for function X_3 and X_7 is larger than the county mean, whereas the money allocated for function X_4 is below the county mean. The implication of these findings is that the pupil/teacher ratio for high schools could be

increased (hence the class size too) and this ratio should be decreased for elementary schools.

The simulation results of Scenario 3 (Table III, col. 10 and 11) denotes that a lower budget ($3150/pupil) will be sufficient to ascertain the desired educational targets (of a "rich district"), providing the community (X_{33}) index (for that district) is $67,187 and each of the pupil qualification indices (X_{35} - X_{38}) have an integer value of one (1). Notice that in this scenario the solution values of both X and X_4 are below the county average. The same can be said for variable X_9 (average teacher salary). On the other hand, the expenditure on functions; X_7 (interscholastic athletics), X_{11} (school library), X_{17} (BOCES - teaching) and X_{19} (contractual, planning/development) should be increased to a level which is above the county average.

Case III - Districts Within a Region (BOCES I)

The simulation of alternative scenarios of a single district were discussed in the preceeding sections, whereas in this section the financial requirements for various types of districts (within a region) are discussed. BOCES I districts (located in eastern Long Island) were selected for this endeavor.

Hence, upon consultation with the Superintendent of BOCES I[1] and his staff member, it was decided to simulate the financial requirements of 3 types of districts; namely low, average and high performing districts.

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[1]BOCES is an acronym for Board of Cooperative Education Services

A single set of desired educational (outcomes) targets, priorities and weights were developed for the various scenarios, whereas the 3 types of districts (denoted by various scenarios) were defined in terms of their community, school and pupil attributes. Hence in this case, just as was done in Case II, certain pupil, school and community variables were bounded on one side only, while others were "pegged" at a given value. Variable X_{29} on the other hand, was "fixed" at "0" because none of the schools of that region have enrollment greater than 3000 pupils. The overhead variables (X_{14}, X_{15}) were also pegged (at 867 and 409 respectively). The solutions for the scenarios of this case are recorded in Table IV that follows. Notice that this table contains 11 columns of information with similar headings to those denoted in the previous table (III).

To simulate the resource requirements for Case III - Scenario 1 (low performing district), the school size (X_{29}) and pupil quality (X_{34} - X_{40}) indices were pegged at a value of zero, whereas variable X_5 was pegged at 50. The community wealth and income indices (X_{32}, X_{33}) were bounded on one side only. Hence, the upper bound of variable X_{33} was set at $44,893 for this scenario. Finally, two budget configurations were used while simulating Scenario 1 of Case III.

The solutions for Case III, as denoted below in Table IV, provide some useful information for the decision making process regarding the educational targets (see column 5, Table IV) according to the simulation results, can be realized under conditions set by the various scenarios

TABLE IV

Case III Simulation Results
East End (BOCES I Dist.)

1 Outcome Variable Code	2 Mean Value	3 Lower Bound Value	4 Upper Bound Value	5 Desired Ed. Target	6 Scenario 1 Solution $3306/Pupil‡	7 Scenario 1 Solution $3113/Pupil‡‡	8 Scenario 2 Solution $3306/Pupil‡‡‡	9 Scenario 2 Solution $3000/Pupil	10 Scenario 3 Solution $3306/Pupil‡	11 Scenario 3 Solution $3000/Pupil‡‡
O_1	.919	.8400	.9900	.919	.91	.91	.91	.91	.91	.98
O_2	.931	.7200	.9900	.941	.94	.94	.94	.94	.94	.99
O_3	.711	.2300	.9300	.861	.86	.86	.86	.86	.86	.86
O_4	.806	.4100	.9900	.886	.886	.93	.89	.88	.86	.86
O_5	.674	.3333	.9324	.884	.88	.88	.88	.88	.97	.94
O_6	.628	.3844	.9267	.788	.86	88	.84	.87	.87	.84
O_7	.520	.2653	.9993	.62	.99	.98	.99	.93	.99	.91
O_8	.749	.1579	.9990	.949	.97	.94	.96	.94	.97	.94
O_9	.584	.2500	.8269	.836	.836	.836	.836	.83	.83	.83
O_{10}	.762	.3846	.9167	.852	.85	.85	.85	.85	.86	.86
O_{11}	.760	.0588	.9608	.86	.85	.85	.85	.93	.85	.85
O_{12}	.810	.4091	.9990	.85	.85	.85	.85	.85	.85	.85
O_{13}	.775	1176	.9990	.845	.98	.92	.98	.90	.98	.93
O_{14}	805	.2747	.9990	.845	.845	.89	.845	.91	.84	.84
O_{15}	.367	.1786	.8511	.307	.50	.50	.50	.50	.50	.50
O_{16}	.280	.1043	.4286	.36	.36	.36	.36	.31*	.50	.36
O_{17}	.313	.0266	.5190	.253	.252	.252	.252	.252	.23	.23
O_{18}	.180	.0068	.4786	.04	.02#	.02#	.02#	.02#	.02	.03

Input Variable Code/Name	Mean Value	Lower Bound Value	Upper Bound Value	SOLUTIONS					
X_1 FRV_2	54.61	9.32	69.17	6	6	6	6	6	9
X_2 FRV_3	89.36	39.35	153.00	39	39	39	39	39	39
X_3 FRV_4	109.34	795.36	1283.74	1243	1470	1087	1359	1320	1088
X_4 FRV_5	1444.61	1083.10	1593.55	1083	1083	1087	1083	1083	1083
X_5 FRV_7	50.72	5.22	120.00	(50)	(50)	(50)	(50)	(50)	(50)
X_6 FRV_{10}	70.01	39.47	143.00	39	39	39	39	39	39
X_7 FRV_{12}	36.05	15.49	55.69	96	32	122	15	86	87
X_8 FRV_{14}	.94	.01	10.00	9	4	9	3	0	6
X_9 FRV_{19}	19781.75	16677.56	24000.00	18743	20737	17366	19757	19421	17379
X_{10} FRV_{20}	31.17	15.94	100.00	16	16	16	16	16	16
X_{11} FRV_{21}	56.03	15.91	76.40	75	53	75	38	75	13
X_{12} FRV_{22}	3.17	.01	10.68	0	0	0	0	0	0
X_{13} FRV_{24}	9.88	2.05	17.07	35	36	33	34	37	33
X_{14} FRV_{25}	1120.82	860.45	1306.08	(867)	(867)	(867)	(867)	(867)	(867)
X_{15} FRV_{26}	530.88	409.45	800.00	(409)	(409)	(409)	(409)	(409)	(409)
X_{16} FRV_{27}	1.32	.01	20.00	0	0	0	0	0	0
X_{17} FRV_{28}	66.73	32.70	140.00	162	72	198	136	145	203
X_{18} FRV_{29}	1.20	.01	3.01	11	11	6	6	0	0
X_{19} FRV_{31}	5.35	.81	12.17	103	61	98	52	92	42
X_{20} FRV_{32}	17.16	3.86	50.00	3	3	3	3	3	3
X_{21} FRV_{33}	8.63	3.22	16.31	3	3	3	3	3	3
X_{22} FRV_{36}	83.89	42.00	140.27	166	76	201	140	149	207
X_{23} FRV_{47}	3.93	.63	25.00	2.48	0.00	0.00	0.00	0	0
X_{24} FRV_{48}	69.77	40.80	120.00	70	40	82	45	75	89
X_{25} FRV_{49}	2.56	.91	8.00	0	0	0	0	0	0
X_{26} FRV_{51}	56.33	31.72	500.00	31	31	31	31	31	31
X_{27} FRV_{52}	21.23	9.30	34.15	9	9	9	9	9	9
X_{28} $TSCP_1$	15.08	5.76	31.02	14.5	13.2	12.2	22.3	7.8	9.1
X_{29} $TSCP_2$	.50	0	1.0	(0.0)	(0.0)	(0.0)	(0.0)	0.0	0.6
X_{30} $TSCP_7$	27.93	20.44	43.92	45.9	31.1	45.9	26.8	45.9	28.2
X_{31} $TSCP_8$	43.45	31.70	58.15	NA	NA	NA	NA	NA	NA
X_{32} CON_2	18683.76	14669.40	22758.90	0.0	0.0	0.0	0.0	0.0	0.0
X_{33} CON_3	76716.81	44893.80	126186.00	0.0	44894.0	0.0	76717.0	0.0	33238.5
X_{34} $APSX_1$	.6	0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
X_{35} $APSX_2$	.5	0	1.0	0.0	0.0	0.5	0.5	1.0	1.0
X_{36} $APSX_3$	.5	0	1.0	0.0	0.0	0.5	0.5	1.0	1.0
X_{37} $APSX_4$	.5	0	1.0	0.0	0.0	0.5	0.5	1.0	1.0
X_{38} $APSX_7$	.6	0	1.0	0.0	0.0	0.4	0.4	1.0	1.0
X_{39} $APSX_8$	.4	0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
X_{40} $APSX_9$	.6	0	1.0	0.0	0.0	0.0	0.0	0.0	1.0

[1] 53 School Districts included (Fishers Island excluded). Upper bound is the mean of the upper 20% of S.D. Similarly, the lower bound is the mean of 20% of S.D.

*indicates objective not met

‡budgetary slack = $337

‡‡budgetary slack = $0

‡‡‡budgetary slack = $367

( )figures in parentheses indicate fixed variable

#indicates dropout (O_{18}) rate exceed the desired target

Note: Budget of $3306 per pupil implys:

$$\sum_{k=1}^{27} C_k X_k \leq 3506 \; , \; k \neq 9,22$$

Where:

C_k = .55, k = 3 (proportion of students K-6)
.45, k = 4 (proportion of students 7-12)
.1, k = 5 (proportion of students under PSEN)
1.0, otherwise

and budget configurations. The distribution of the alternative budget configurations over the various educational functions, also contain some policy implications. For instance, the value of X_3 is above the county average for the two budget configurations (see col. 6, 7, Table V), whereas the value of X_4 is below that average. The implication thereof is that the pupil/teacher ratio should be decreased for elementary schools, whereas that ratio should be increased for high schools of a poorly performing district. Moreover, the simulation results call for a larger amount of money to be allocated (by that district) for education functions such as: X_{17} (BOCES - teaching) and X_{19} (contractual-adm./planning/improvement). Finally, the results indicate that a poorly performing district could realize the desired educational targets with the lower budget (i.e., $3150/pupil), providing the community wealth index is at least 4,894. These targets, however, are ascertained (by the technique) through the shifting of financial resource. Hence, under the lower budget configuration money is shifted away from supporting functions or services (i.e., X_7, X_{17}, X_{19}, X_{22} and X_{24}) into direct educational functions (i.e., X_3 and X_9). Notice that the similar shifting of funds can be found in Scenario 2 solutions.

In Scenario 3 (well performing districts), on the other hand, the money shifting phenomenon is reversed. In other words, money is shifted from direct educational functions (i.e., X_3 and X_9) into indirect educational functions (i.e., X_7, X_{17}, X_{22}, X_{24}) whenever the budget is reduced (from $3506/pupil to $3000/pupil). Recall that well performing districts

in this case are denoted by the value of one (1) for most "pupil quality" indices (X_{34} - X_{40}). That is to say that a well performing district is "endowed" by pupils who "scored" in previous year tests, above the county average.

B. The Administrative Structure of a District and Pupil Performances.

Simulation results for the second policy predicament were not ascertained as of this writing. However, a prototype model was developed.

In constructing this model, we have conceptualized the school district to be a system that can be broken down into a set of relatively autonomous educational and administrative "sectors." The linkages among these sectors has been conceptualized in terms of organizational theories in general and of intersectorial work flow processes concerning grades 3, 6, 9 in particular. The "sectors" of this model are listed in Table V.

A stratified sample of pupils (flow and activities) was used as common units of analysis to denote such linkages among the units (sectors) of the system and to construct the model. The exploratory nature of this mode has precluded the extraction of an exhaustive set of information from the model. The computer printout has merely highlighted the capabilities of the model. In a subsequent working paper we will attempt to provide the reader with a comprehensive view of the structures and processes of the educational system as a whole. This would be realized through the utilization of an improved data collection and recording procedures [see Spottheim et al working paper No. 13, May 1984].

THE ADMINISTRATIVE STRUCTURE AND
PUPIL PERFORMANCE OF A SCHOOL SYSTEM
HUNTINGTON UNION FREE SCHOOL DISTRICT

TABLE V

LIST OF THE SYSTEM'S ELEMENTS
(Grades-3,6,49 Only)

Sector No.	Data Code		Sector No.	Data Code	
		I. HOME FAMILY ENVIRONMENTS			Income:
		Student's Birthplace:	30	HF_{30}	Low Income
1	HF_1	USA	31	HF_{31}	Medium Income
2		Default - birthplace			Siblings:
3	HF_3	Asia	32	HF_{33}	Brother/Sisters - 3 or less
4	HF_4	Other	33	HF_{34}	Brothers/Sisters - More than 3
		Ethnic:			Family:
5	HF_5	Caucasian	34	HF_{35}	Intact
6	HF_6	Black	35		Default - Siblings
7	HF_7	Hispanic - Caucasian	36		Default - Family
8	HF_8	Hispanic - Black	37	HF_{38}	Other than Intact
9	HF_9	Default - ethnic			II. TEACHER QUALIFICATIONS
10	HF_{10}	Oriental	38	T_{53}	BA
11	HF_{11}	Other	39	T_{54}	BA + 30
		Father's Education:	40	T_{55}	MA
12	HF_{12}	Elementary School	41	T_{56}	MA + 15
13	HF_{13}	High School	42	T_{57}	MA + 30
14	HF_{14}	College	43	T_{58}	MA + 45
15	HF_{15}	Graduate School	44	T_{59}	MA + 60
		Father's Occupation:	45	T_{60}	Ph.D.
16	HF_{16}	Professional			Experience:
17	HF_{17}	Managerial	46	T_{61}	Less than 5
18	HF_{18}	Blue Collar	47	T_{62}	6 - 10
19	HF_{19}	White Collar	48	T_{63}	11 - 15
		Previous Test Results and Defaults:	49	T_{64}	16 - 19
20	PT_{20}	3rd Grade Reading/Math Pass	50	T_{65}	20+
21	PT_{21}	3rd Grade Reading/Math Fail			License - Elementary School:
22		Default - father's education	51	T_{66}	Special Ed.
23		Default - father's occupation	52	T_{67}	Common Branch
24		Default - Previous Test	53		Default - Elem. License
25	PT_{25}	Failed in Math	54	T_{70}	Reading
26	PT_{26}	Pupil not Tested & Other	55	T_{71}	ESL
		Language Spoken at Home:	56	T_{72}	Art and Music
27	HF_{27}	Spanish	57		Default - Secondary Teacher License
28	HF_{28}	French			
29	HF_{29}	Other			

Sector No.	Data Code		Sector No.	Data Code	
		Secondary Teaching License:			G. Art
58	T_{74}	Social Studies	90	A_{219}	Creative Crafts
59	T_{75}	Math	91	A_{220}	Basic Art
60	T_{76}	Science	92	A_{225}	Ceramic Sculpture
61	T_{77}	English			H. Industrial Art & Home Art
62	T_{78}	Combination	93	I_{232}	Woodworking
		III. SUBJECTS TAKEN BY PUPIL	94	I_{233}	Metal Work
		A. Grade K-6	95	I_{244}	Power Mechanics
63	E_{79}	Common Branch	96	I_{247}	Foods
64	E_{84}	Gifted			I. Business Education
		B. Language Arts (English)	97	B_{254}	General Business
65	L_{87}	English 9	98	B_{255}	Typing - Full
66	L_{90}	Communications 9	99	B_{256}	Typing - 2 times
67	L_{97}	English 11 Y			J. Pupil Services
68	L_{102}	Reading	100	PS_{284}	Wilson Tech
		C. Foreign Language	101	PS_{290}	Resource/Aide
69	F_{116}	Chinese I			IV. OUTPUTS
70	F_{120}	ESL			A. Exams (Elementary School)
71	F_{123}	French	102	Q_{291}	Reading Exam 3rd Grade
72	F_{124}	French I	103	Q_{294}	Reading Exam 6th Grade
73	F_{125}	French II	104	Q_{296}	Stanford Achievement Test - Reading (9th Grade)
74	F_{130}	German I			V. RESULTS OF TESTS(CLOSURES)
75	F_{133}	Italian I	105	X_{330}	3rd Grade Exams Pass (Reading or Math) i.e., above SRP
76	F_{136}	Latin I	106	X_{331}	3rd Grade Exams Fail (Reading or Math) i.e., below SRP
77	F_{140}	Spanish	107	X_{334}	6th Grade Exam (Reading or Math) Pass i.e., above SRP
78	F_{144}	Spanish III	108	X_{335}	6th Grade Exam (Reading or Math) Failed i.e., below SRP
		D. Math	109	X_{341}	Stanford Achievement Exam (9th Grade) Pass
79	M_{152}	Math Skills	110	X_{342}	Stanford Achievement Exam (9th Grade) Fail
80	M_{154}	General Math	111	X_{354}	Unknown Results/Default - Test Results
81	M_{155}	Sequential Math I	112	X_{355}	Dropout/Default - Output sec.
82	M_{156}	SSMCIS 9	113	X_{357}	Error
83	M_{157}	Seq. Math I			
		E. Science			
84	S_{174}	ISCS			
85	S_{175}	Earth Science			
86	S_{176}	Small Engines			
87	S_{177}	T.V. Production			
88	S_{178}	Photography			
		F. Social Studies			
89	SS_{197}	Social Studies 9			

VI. SUMMARY

In the preceeding pages, the application of economic concepts and various quantitative methods to the problems of allocating of educational resources within school districts were discussed at length, and a few concluding remarks concerning this endeavor are presented below.

As was noted earlier in this Summary Report, an attempt was made to use educational economics and management science concepts along with corresponding quantitative methods to analyze the resource allocation problems. Thus, threaded throughout this research endeavor are concepts concerning:

- educational production function
- efficacious resource allocation within school districts
- pupil flow within the existing operational structure of a school system.

Hence, three models were constructed. The first is a descriptive model, portraying the relationships between educational expenditures incurred, and the outcomes produced by school districts. A resource allocation procedure (goal programming) was then used in conjunction with this model. This amalgamated approach was used to determine the composition of financial resources needed to realize educational goals for various kinds of districts. Finally, a prototype model portraying operational structure of a school system and its outcomes was developed. Notice that the common units of analysis of this model are pupils, while the units of analysis of the former two models are school districts.

These models were developed, inasmuch as they can be used to:

- understand and clarify the predicaments in question
- complement the judgement process
- improve the decision making process (see Ignizio 1982).

The central conclusion of the effort discussed thus far is that an array of educational data can be reduced into a manageable set of equations through the application of the aforementioned concepts. Furthermore, it has been demonstrated that such equations which summarize certain observed educational phenomena, can be used to address certain educational predicaments. Specifically, it has been demonstrated in this study that:

- the relationships between educational means and ends can be quantified (into a model) through the application of an economic theory and its quantitative counterpart.
- multi-objective decision analysis techniques can be applied (in conjunction with the above mentioned model) to the problem of efficacious resource allocation within school districts so as to ascertain preemptive educational goals.
- the complex organizational structure of a school system, and its outcome, can be mathematically represented through the application of an amalgamated approach which reconciles organizational theories and a management sciences technique.

The refinement of the procedures presented in the final report, is based on the assertion that the effectiveness of any applied (or empirical) methodology rests on its ability to address existing or anticipated policy issues of the educational system under study.

Hence, to refine the operational capability of the models, some improvements have been suggested. For instance, the pupil performance model presented earlier can be improved through the calibration of a retrospective model with interactive and lagged explanatory variables, whose coefficients are simultaneously estimated (for selected subset of equations) via an ML technique. The goal programming model, on the other hand, could be replaced and/or complemented by a "piecewise" linearization technique. Finally, the pupil flow model could be enhanced through improvement of the data collection procedures.[4]

In sum, the application of the methodologies discussed thus far should not be viewed as a mysterious process. Rather, they were used as a tool to extract relevant properties from numerical data concerning educational finance. Thus, it was demonstrated by this effort that an array of educational data can be reduced into a manageable set of equations through the application of educational economic concepts and quantitative methods. The models produced through the application of this approach were used to address the aforementioned policy predicaments.

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[4]Such an enhanced model could then be used in conjunction with a "multiobjective decision technique," for the purpose of simulating the optional "pupil flow" (within the system) that may lead to the attainment of desired (educational) outcomes.

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